Partial Fourier Reconstruction in MRI

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Abstract **- Magnetic Resonance Imaging (MRI) is limited by the time needed for imaging. Partial Fourier (PF) is a way for reconstructing the image by using a lesser data, and hence shorten imaging time. The current PF techniques suffers from artifacts in the reconstructed image due to the presence of non-linear phase errors in MRI raw data. The current paper illustrates how an optimization in PF algorithm, like PoCs, is feasible through enhancing truncation and merging filters. The outcomes were evaluated through a quantitative and a qualitative criteria, and showed a better results.**

keywords **- MRI, partial reconstruction, windowing, optimization, PoCs.**

I. Introduction

Magnetic Resonance Imaging (MRI) is a superior imaging modality in terms of contrast for soft tissues, and also due to its various applications, e.g. probing biological functions as brain's [Functional MRI], or characterizing materials within human body [1, 2]. Further, what set MRI apart from other imaging methodologies is that it has no harmful ionizing radiations that exist in X-ray or CT.

However, MRI imaging session is relatively long in time. Patients immobility introduces an artifacts in the final image boosted by the long time of imaging. Also, it limits the extent of MRI applications, i.e. the speed of biological changes is so fast that it may not be captured in good resolution like what happens in Functional MRI, for example [3, 4]. Further, the cost per scan is increased when the required time is lengthened [5].

Partial Fourier (PF) reconstruction is a technique used to reconstruct the final MRI images using only a part of the raw data needed for full image reconstruction [6]. Thus, the long time of imaging ,caused by MRI data acquisition stage, is shortened by a fraction corresponds to the fraction of the partially used data for MRI reconstruction.

Unfortunately, the current PF algorithms are not optimal, and introduce artifacts in the final reconstructed images. This paper suggests an optimization in performance through windowing enhancement, and it is extracted from a master thesis by the author [7].

II. Background

PF has various synonymous terms in the literature, e.g. half Fourier [8], half scan [9], asymmetric [10], one-sided [11], under-sampled [12], and phase constrained reconstruction [6]. Among the firsts who conducted PF imaging in MRI was Feinberg et al. [13]. He employed the well known property used in magnetic spectroscopy, conjugate symmetry. This property from author perspective is an inherent feature of Fourier transforms (FT). Due to the presence of phase errors which destroy the base assumption of conjugate symmetry, Margosian and Schmitt [14] used a symmetric part of MRI raw data to estimate the phase errors and compensate it. Their method is based on the existence of only a linear phase errors, which is an ideal assumption, because there are non-linear phase errors as well. To mitigate these limitations, other methods had developed and followed an iterated reconstruction algorithms that converge to the estimated solution. The top performance algorithm that was chosen to work with and to optimize is projection onto convex set (PoCs) [15, 16].

The FT is the commonly used tool for image reconstruction. When the Fourier plane (MRI raw data) is finite, which is always the case, artifacts (Gibbs ringing) near the high contrast interfaces will occur. Also, in the last step of PF iterated algorithm, and at the integration (merging) interface of original MRI raw data and synthesized data, if the transition was rough at that area, the same Gibbs ringing artifacts will be shown. The methods followed for windowing and smoothing are crucial for better outcomes.

III. Methodology

The MATLAB programming environment (R2014a) was used to simulate PF reconstruction process. A full raw MRI data was windowed by a heavy-side filter along the phase-encode direction to mimic PF raw data acquisition. A (137), of a total (255), phase encodes was left after applying the heavy-side window, that means the factor of PF is (0.537). The code used for PF reconstruction was made by an integration of Two codes, one supplied from Prof. Yasser Kadah for MRI images handling [17], the other was downloaded from Mathworks' website, and used as the main code for PoCs [18].

Two filters in PoCs were optimized, the truncation filter for the symmetrical part used to derive the phase estimate, and the merging filter used to smooth the joint area between the original and reconstructed MRI raw data. The symmetrical filter used in the original PoCs was Hann. The researcher replaced this filter by a Gaussian filter after an operation of taking the power of (0.95) on point-to-point bases (Fig. 1 & 2). The merging filter in the original PoCs was five points wide, calculated by making 13 points Hann filter, and then taking the last Five points after dropping the last one (Fig.3). The optimized merging filter was calculated by taking the power of (0.0000000001) on point-to-point bases (Fig. 4).

The area under the curve of the enhanced merging filter in Fig. (3 & 4) represents the fraction taken from the original data. Whereas the fraction complement (1 – filter) is taken from the synthesized interpolated data.

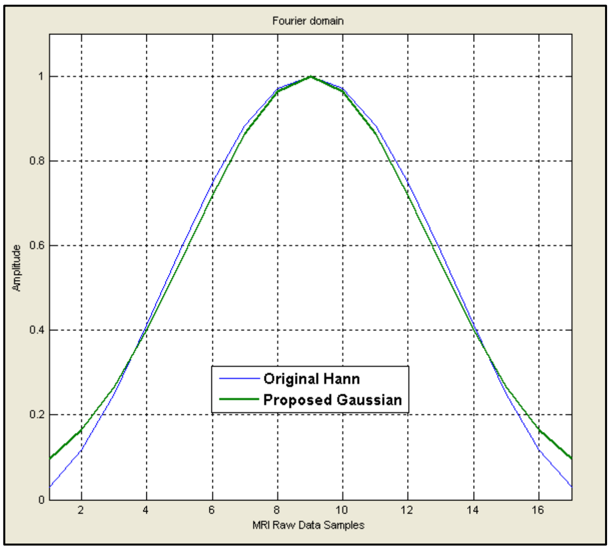

Fig. (1) Original Hann vs. Proposed Gaussian window.

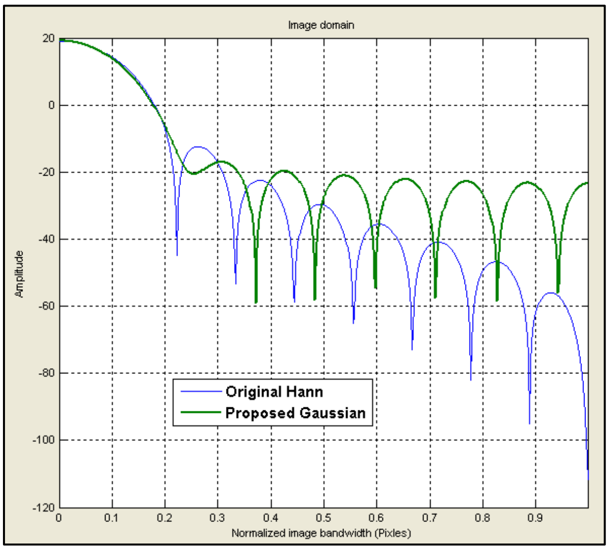

Fig. (2) Original Hann vs. Proposed Gaussian Response.

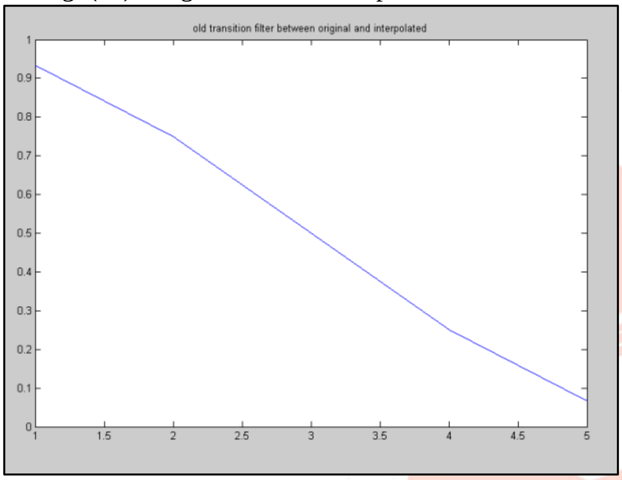

Fig. (3) Original Merging filter.

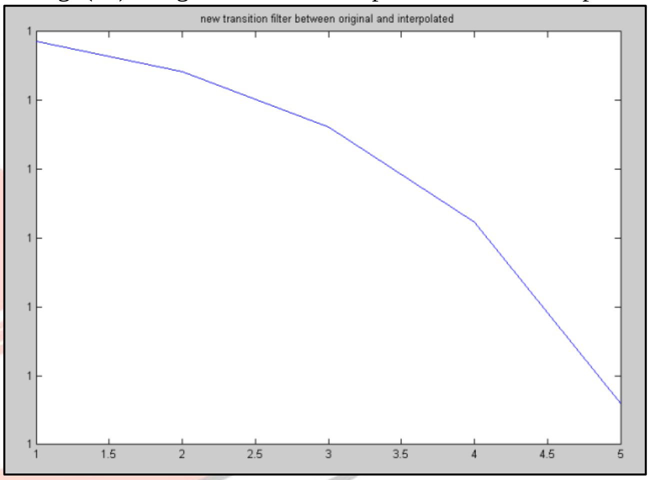

Fig. (4) Modified Merging filter.

The mean square error (MSE) between the original MRI image, reconstructed from the full raw data, and the PF PoCs reconstructed image, was used to evaluate the performance. In addition, a qualitative approach was followed to judge the differences using sight with the help of a colored encoded difference image.

IV. Results

The MSE was reduced [(from 9.4787 to 9.1702) $\times 10^{-6}$] after applying the modified symmetrical and merging filter. The qualitative sight comparison indicated an obvious improvement around sinuses where air-bone interface is present (Fig. 5 & 6).

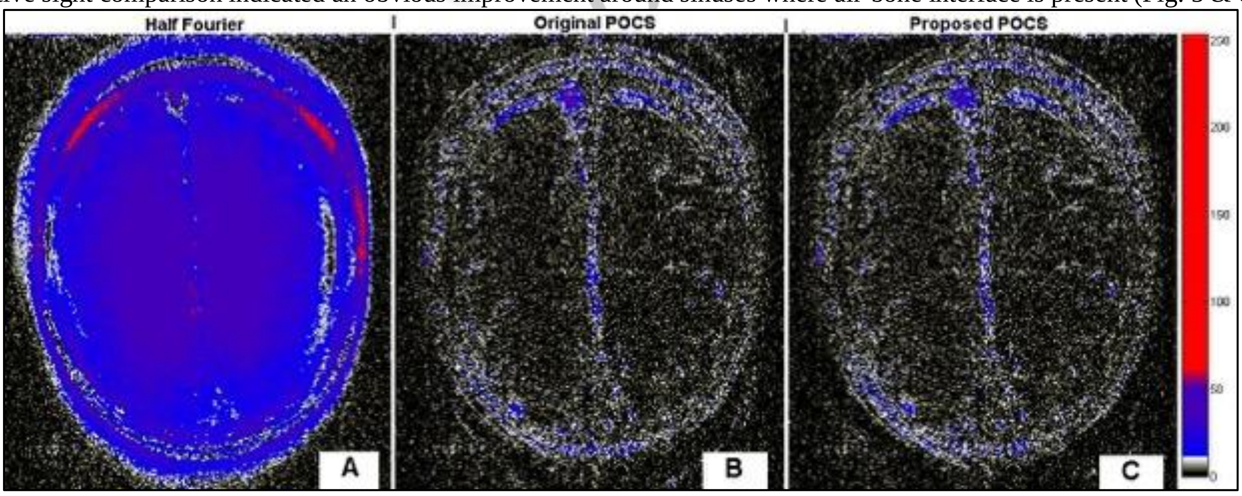

Fig. (5) Difference Images for PF with Reference to The Image Reconstructed From Full Raw Data For: (A) Half Fourier without phase correction; (B) Original PoCs, and (C) Modified PoCs.

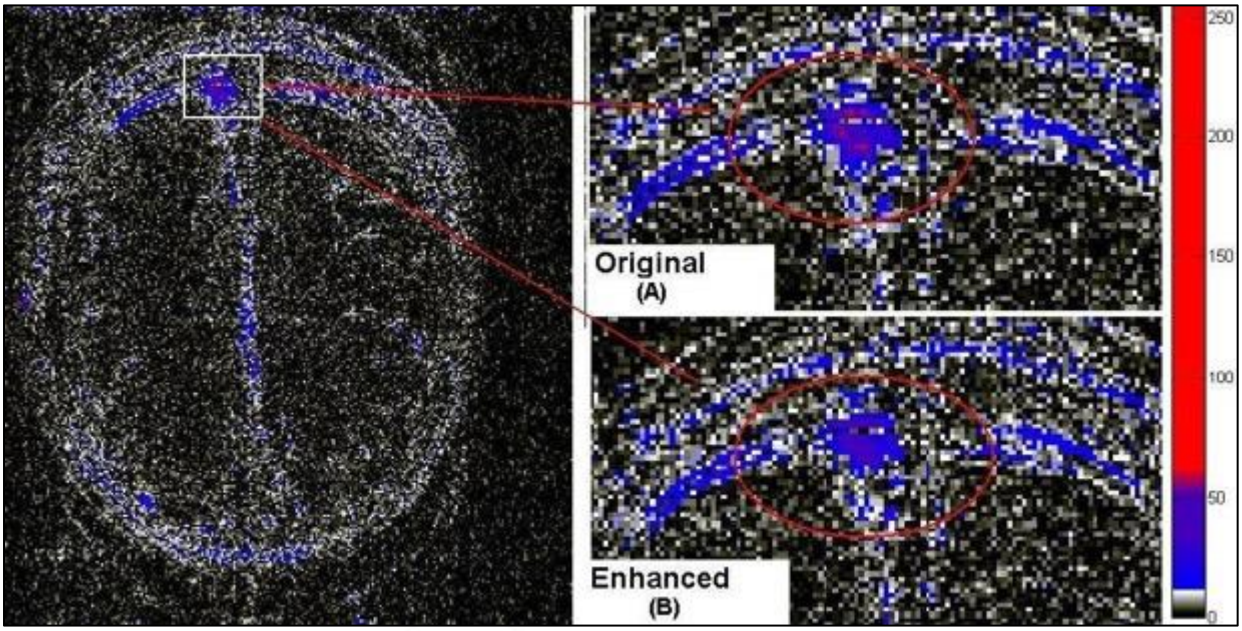

Fig. (6) Zoomed Difference Images for PF with Reference to The Image Reconstructed From Full Raw Data For: (A) Original PoCs, (B) Modified PoCs.

V. Conclusion

There are room for further enhancement on the current PF techniques found in the literature.

VI. Limitations

The noise in the Black background of MRI PF reconstructed images were not excluded when MSE calculations were conducted. So, if only the region of interest was involved in the calculation, the results would be more reliable. Also, the nature of filters' performance maybe an application specific. Therefore, the performance could vary from an image to another, hence, more images is recommended to incorporated in future research.

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